Revision Arthroplasty in Vancouver B1 Periprosthetic Hip Fractures

Artroplastia de Revisão em Fraturas Peri-Protésicas da Anca Vancouver B1

João C. Pereira [1]*, André Moreira [1], André Costa [1], Guilherme Correia [1], João B. Tinoco, Pedro Varanda [1], Eurico B. Rodrigues [1]

1. Serviço de Ortopedia e Traumatologia, Hospital de Braga, Braga, Portugal

https://doi.org/

ABSTRACT

Introduction: Periprosthetic hip fractures (PHF) represent an important complication after hip arthroplasty. The management of Vancouver B1 fractures remains elusive. While most stems may present radiographically as stable, stem fixation may in fact be compromised. Choosing plate osteosynthesis as a treatment in this type of fractures, trusting radiographic studies alone may lead to implant failure.

Methods: We reviewed 10 years of our institution´s clinical records (2011-2021) and found a total of 161 PHF. Twenty five cases of B1 periprosthetic fractures were included in our study, after their presenting radiographs were blindly reviewed. All PHFs were submitted to arthrotomy, dislocation and stability assessment. Stable implants were submitted to plate osteosynthesis, and unstable implants were submitted to revision arthroplasty. Demographic information, duration of surgery, blood loss, inpatient complications, functional outcomes, and outpatient outcomes and complications were recorded. Mean time of follow-up was 47 months.

Results: Seventy-two percent of of initially classified B1 type fractures presented with a loose stem and required revision arthroplasty. Time until supported ambulation was lower in the revision arthroplasty group (p= 0.01) while surgical time, blood loss after surgery, and inpatient complications presented similar results in both groups. Negative outpatient outcomes showed similar rates in both groups.

Conclusion: Most radiographically well-fixed implants were in fact unstable. Stability assessment using radiographic studies alone proves insufficient and may lead to inadequate osteosynthesis treatment. As such, in-operative stability testing in all B1 type fractures is paramount. Revision arthroplasty permitted early ambulation and showed no greater complications when comparing with osteosynthesis.

Keywords: Arthroplasty, Replacement, Hip; Periprosthetic Fractures/diagnosis; Periprosthetic Fractures/surgery; Postoperative Complications; Reoperation

Autor Correspondente/Corresponding Author: João Carvalho Pereira [jldcpereira@gmail.com], Serviço de Ortopedia e Traumatologia, Hospital de Braga, Sete Fontes, São Vítor – 4710-243 Braga

Recebido/Received: 2024/01/16 **Aceite/Accepted:** 2024/03/17 **Publicado online/Published online:** 2024/04/09 **Publicado/Published:** 2024/06/03

RESUMO

Introdução: As fraturas peri-protésicas da anca (FPPA) são uma importante complicação das artroplastias da anca. A gestão das fraturas Vancouver B1 é controversa. O diagnóstico errado destas fraturas pode levar ao seu tratamento inadequado e a complicações associadas. A artroplastia de revisão nestes casos constitui um tratamento complexo e pouco estudado.

Métodos: Foram revistos os registos clínicos da nossa instituição correspondendo ao período de 10 anos (2011--2021) descrevendo-se 161 FPPA. Após revisão cega das radiografias, 25 casos de fraturas peri-protésicas B1 foram detetadas. Todas as FPPA foram submetidas a avaliação de fixação da haste. As fraturas com implantes estáveis foram submetidas a osteossíntese e as restantes foram submetidas a artroplastia de revisão. Foram colhidos dados demográficos, sobre a duração da cirurgia, a variação de hemoglobina peri-operatória, complicações hospitalares, resultados funcionais e complicações no período de seguimento. O tempo médio de seguimento foi de 47 meses.

Resultados: Das fraturas inicialmente classificadas como tipo B1, 72% apresentavam haste não-fixa. O tempo até deambulação foi menor no grupo de artroplastia de revisão (p= 0,01). O tempo cirúrgico, a variação de hemoglobina peri-operatória, e as complicações do internamento apresentaram resultados semelhantes nos dois grupos. No período de seguimento, a taxa de complicações foi semelhante nos dois grupos.

Conclusão: A maioria dos implantes radiograficamente classificados como fixos eram instáveis e foram submetidas a artroplastia de revisão. Consideramos fundamental a realização de testes de estabilidade em todas as fraturas tipo B1. A artroplastia de revisão permite carga precoce no período pós-operatório associada a uma baixa taxa de complicações.

Palavras-Chave: Artroplastia da Anca; Fraturas Periprotésicas/cirurgia; Fraturas Periprotésicas/diagnóstico; Complicações Pós-Operatórias; Reoperação

INTRODUCTION

In the treatment of hip degenerative and traumatic diseases, hip arthroplasty has gained a significant relevance. According to Organisation for Economic Co-operation and Development (OECD) data, the mean *per capita* hip arthroplasty rate stands at 182 per 100 000 people, and is currently increasing.[1] An increasingly older population and a present higher demand for sustained life quality may explain this increasing trend. Simultaneously, improving clinical results lead to hip arthroplasties being performed in an increasingly larger and also younger population.[2,3] As such, the number of individuals at risk for severe hip arthroplasty related complications, such as peri-prosthetic hip fractures (PHFs), is increasing.

PHFs are important hip arthroplasty complications, representing the third most common cause of hip revision arthroplasty, following aseptic loosening and dislocation.[3] Although the precise incidence is unknown, recent studies point to a PHF rate of 0.1%-2.3%,[4] with higher rates being recorded in revision arthroplasties.[5,6] Osteoporosis, female gender, and age over 65 years are the main risk factors for this pathology. Most of these fractures are the result of low-level falls.[6,7] PHF are an important cause of morbidity and mortality as it is estimated that up to 50% of PHF patients do not return to previous autonomy levels.[8,9] Post-PHF mortality rates are high as some studies point to 1-year mortality rate approaching 10% of cases.[10-12] Furthermore, the treatment and rehabilitation of these fractures proves to be a resource -consuming factor in healthcare systems. Previous studies performed in the British healthcare system point to a mean cost per episode of 23 000 – 31 000 £, with costs associated with post-operative in-hospital and rehabilitation care accounting for 80% of the total cost.[13,14]

One of the most commonly used classifications regarding PHFs is the Vancouver classification, established in 1995.[15] This clinically validated classification is based in radiographic studies,[16,17] which determines treatment based on the stability of the femoral implant - Osteosynthesis is indicated for implant--stable fractures (A, B1 and C) and revision arthroplasty is indicated for in implant-unstable fractures (B2 and B3).[18]

Vancouver type B1 fractures are challenging fractures to both diagnose and treat. According to previous studies, they represent 30% of total PHF,[4,19] and are associated with high rates of complications and re-operation.[4] These unsatisfactory results are often explained by pre-operative incorrect classification. Previous studies report varyingly rates of radiographic/intra-operative concordance[20,21] and, as such the acuity of radiological evaluation of B1 type fractures is not fully understood. This knowledge is important as

it determines two totally different philosophies in treatment. If the radiographic-only method of determining stem stability in PHF is trustworthy then a direct approach to the femoral shaft in order to preform osteosynthesis is a reasonable strategy. If, on the other hand, the radiographic evaluation is insufficient, intra-operative stem-fixation testing should be performed, with the inherent morbidity of a more invasive and soft-tissue damaging strategy.

The main objective of this study is to determine the rate of fixed stem PHFs in radiographically classified B1 type fractures through intra-operative fixation assessment. We also aim to compare the clinical results and complication rates comparing osteosynthesis (OS) and revision arthroplasty (RA) in the treatment of Vancouver B1 fractures.

This study was approved by our institution´s ethical committee.

METHODS

In this study we included all recorded cases of PHFs in our institution from January 2011 to December 2021. PHFs initially classified at hospital admission as Vancouver B1 type fractures were selected. Radiographic studies were then blindly reviewed by one hip pathology orthopaedic surgeon. Upon comparison with pre-trauma radiographic exams, cases with radiographic signs of stem migration or significant osteolysis around the stem fixation area (type B2 and B3) were excluded. Additionally, cases with fracture lines around the greater and lesser trochanter (type A1 and A2) and bellow the tip of the stem (type C) were excluded.[7] All cases of the remaining Vancouver B1 type fractures were submitted to intra-operative stem fixation evaluation. This consisted of arthrotomy, surgical dislocation, stem-bone interface integrity visual and tactile evaluation and, most importantly, stem longitudinal traction. The cases upon which the stem was loose were submitted to revision arthroplasty with a diaphyseal fixation stem and the remaining cases comprising of fixed stems were submitted to plate/steel cable osteosynthesis. Demographic, clinical and impatient related data, and complications were recorded (Table 1). Statistical analysis was performed using SPSS v.27 (SPSS, Inc., Chicago, IL). Chi-square, Mann-Whitney U and Fisher´s exact test was employed as indicated. Statistical significance was $p<0.05$. Mean follow-up time was 47 months.

RESULTS

Of the total 161 PHF recorded during the study period, 47 cases of B1 type fractures were registered in the clinical records. After radiographic evaluation, 22 cases were excluded due incorrect classification. As such 25 cases were included in this study. Mean patient age was 78.5 years, 60% (n=15) of which were female. 96% (n=24) resulted from low-energy trauma. 24% (n=6) needed external ambulatory support pre-fall. The most common primary pathology was osteoarthritis (80%, n=20). A percentage of 92% (n=23) of fractures occurred in total hip arthroplasties with the remaining 8% (n=2) representing hemi-arthroplasties. And 80% (n=20) of all implants were non-cemented (Table 1).

After intra-operative examination, 72% (n=18) of stems were found to be loose. Accordingly, all loose implants were submitted to RA and the remaining fixed implants were submitted to OS. Median age of implant at the time of fracture was 9.9 years, (RA=6 *vs* OS=17.14 (years) $p= 0.144$).

After comparing both groups we noted that assisted walking started in the in-hospital time in a higher percentage in the RA group vs the OS group (77.8% *vs* 14.3%; $p= 0.007$). Similarly, time until assisted walking was shorter in the AR group when comparing to the OS group (4.5 days *vs* 72 days; $p = 0.01$).

As for the intra-operative/in-hospital results (Table 2), the intra-operative duration was similar between the two groups, with a slight longer time in the RA group (90.1 min. (+/-32.1) *vs* 84.1 min. (+/-20.2), $p= 0.7$). Post-operative haemoglobin decrease was similar in the two groups (RA- 3.7 (+-2.1) *vs* OS 3.3 (+-1.2); $p= 0.7$). As for in-hospital complications, four in total were recorded in the RA group and two in the OS group, (28.6% *vs* 22.2%; $p = 0.6$) (Table 3). The mean time of in-hospital stay was shorter in the RA group, although this result was not statistically significant (RA= 9 (5-28) *vs* OS= 15 (6-27) (days); $p= 0.4$).

Complication rate during the follow-up period (Table 4) was similar in both groups. Four cases of arthroplasty instability were recorded in the RA group (26.7%), two mechanical failures in the OS group (28.6%) and one infection in the OS group as well (14.3%). One-year mortality rate was 4%. No fracture showed signs of non-union during the follow-up period.

Tabela 1. Sample Demographics

Variable	Results
N	25
Sex (Female)	15 (60%)
Mean age (years)	78.5 (+/-11.1*)
Previous walking support	6 – (24%)
Low-energy trauma	24 - (96%)
Primary implant	23 THA † (92%) 2 Hemiarthroplasties (8%)
Non-cemented stems	20 (80%)
Primary pathology	20 (80%) – Osteoarhtritis 4 (16%) –Femoral neck fractures 1 (4%) –Osteonecrosis
In-hospital mortality	1 (4%)
Follow-up (months)	47 (+/-31*)
*-standard deviation; † - THA – total hip arthroplasty	

Tabela 2. Results

	OS	RA	*p* value
N	7 (28%)	18 (72%)	-
In-hospital deambulation (n)	1 (14.3%)	14 (77.8%)	0.007 †
Time until weight bearing (d)	72 (2-269)	4.5 (1-20)	0.01 *
Intra-operative time (min)	84,14 (+-20.21)	90,12(+-32.13)	0.7 ‡
Hemoglobin decrease (mg/dl)	3.34 (+-1.19)	3.66 (+-2.05)	0.7 ‡
In-hospital complications (n)	2 (22,2%)	4 (28,6%)	0.6 †
Hospital stay duration (d)	15 (6-27)	9 (5-28)	0.5 *
*-Mann Whitney-U, † -Fisher´s exact test; ‡- Independent t test			

Tabela 3. Recorded in-hospital complications.

Complications	OS	RA
Acute heart failure	1	2
Acute renal failure	-	1
Acute pneumonia	-	1
Pressure ulcers	1	-

Tabela 4. Recorded outpatient complications during the follow-up period.

Variable	OS	RA	*p* value
Time until sitting ability (d)	3(2-14)	2 (1-11)	0.091 *
Dislocation (n)	0 (0%)	4 (26.7%)	0,3 †
Mechanical failure (n)	2 (28.6%)	0 (0%)	0,091 †
Bone consolidation (n)	3 (42.9%)	12(80%)	0.145 †
*-Mann Whitney-U, †- Fisher´s exact test.			

DISCUSSION

PHF treatment is a complex subject and it requires a surgical team experienced in both revision and traumatological surgery in order to attain good results.[7] Regarding this challenging pathology, correct diagnosis is key. It is therefore of the upmost importance to establish the adequate correlation between the radiologic and intra-operative findings. Originally, according to the Vancouver classification, osteosynthesis in type B1 PHF was indicated using only radiological evaluation, relinquishing the need for revision surgery, *a priori.*[15,22] Further studies proved that radiological studies were not fully reliable, and, when decision was made solely based on them, treatment failure and re-intervention rates were high.[23]

After analysing PHFs in this study, we face two major findings. Firstly, after blind radiological review, of the initial 47 cases listed as B1 type-fractures, only 25 fulfilled the criteria for B1 PHFs. Secondly, the rate of non-fixed stems in radiologically diagnosed B1 PHFs was 72% (n=18). This high rate of discordance is comparable to the available literature.[4,21,24] These two findings translate the fact that the surgical team must always be prepared for a revision surgery, regardless of the radiological evaluation.

Our study included 25 patients with an advanced mean age (78.5), most of them women (60%). The majority of injuries occurred because of low-level falls in patients with a pre-injury low autonomy level. As for the primary implant, 92% of the cases were total hip arthroplasties, 80% of them were due to osteoarthritis and 20% of the stems were cemented. The clinical data was similar to past studies addressing this pathology,[2,24-27] which leads us to conclude that our sample is fairly representative.

Within the RA group, both a higher percentage of patients were able to perform in-hospital ambulation (77.8% RA *vs* 14.3% OS, *p*= 0.007) and the time until ambulation was shorter in this group (4.5 days (RA) *vs* 72 days (OS), *p*= 0.01). These results can be explained by the fact that femoral component revision arthroplasty allows for the weight of the patient to be transmitted distal to the fracture which permits early load-bearing post-operatively.[7,28] Opposingly, in order to prevent early implant failure, cases submitted to OS were only allowed to perform full weight bearing after showing radiographic signs of fracture consolidation, thus explaining the significant longer time until ambulation. Laurer *et al*, has previously described better functional results regarding revision arthroplasty, when comparing with osteosynthesis, in radiologically classified B1 type fractures.[26] Furthermore, the clinical results regarding post-operative haemoglobin levels decrease, in-hospital medical complications and out-patient complications (mechanical failure, infection, and implant instability) were similar among the two groups (Tables

2, 3 and 4). As such, the overall treatment morbidity of RA was comparable to OS. Akin to these results, some studies have reported non-inferior overall complication rates when comparing RA versus OS treatment.[23,26] All except two cases consisted of fractures that occurred more than one year after primary arthroplasty (mean age= 9.9; RA=6 *vs* OS= 17.14, p= 0.143). As such, implant longevity did not seem to predict stem fixation and subsequent surgical outcome.

In this study, 28.6% (n=2) of the OS group presented signs of mechanical failure during the follow-up period. This complication is well-known in the scientific literature,[12,25,26,29,30] and implies a high rate of conversion to revision arthroplasty, with all the inherent morbidity associated with a second operation.[26,27] This problem is often explained by the inadequate classification of B2 type fractures as B1 type fractures which may lead to inadequate surgical indication and treatment failure.[21,23] However we know that in this study all of the PHFs which were treated with OS were tested intra-operatively and considered stable. As such, other explanations must be considered. PHF osteosynthesis often depends on a low quality, often osteoporotic bone with associated and implant-induced osteolysis.[7,11] Furthermore, desperiostation by either plate or wire osteosynthesis decreases periosteal blood supply in a femur with an already damaged endosteal blood supply. These factors may contribute to early-onset mechanical failure.

A drawback of performing intra-operative stem fixation testing in all PHFs is the higher soft-tissue damage that occurs secondary to arthrotomy and surgical dislocation. This may lead to a higher risk of future dislocation,[21] a fact that is further exacerbated by the muscle weakness associated with the advanced age of this patient population.[31]

In our study, there was only one case of infection which led to the need of debridement and revision surgery, in the OS group (4%). This dreaded although rare complication represents an important cause of morbidity for PHF patients.[23,25] Treatment of PHF is by itself a risk factor for infection, as surgical treatment is performed in a previously operated limb. Furthermore, some studies point to a higher risk of infection associated with osteosynthesis when comparing to revision arthroplasty in this type of patients.[23] With only one case of infection we cannot, however, make any conclusions regarding the risk factors for this complication.

An important conclusion extracted from this data is that, after intra-operative fixation assessment, only 4% of all PHFs could be classified as B1. This percentage is significatively lower than that achieved by pure radiological classification and is also lower than what has been described in previous PHF series.[4,24] This low rate of true implant fixation should make the surgical team consider revision arthroplasty in all cases of B1 type fractures, regardless of the radiologic study. Furthermore, due to the inherent subjective nature of intra-operative stem fixation assessment, stem non-fixation should always be suspected, and revision arthroplasty consider avoiding further complications associated with incorrect osteosynthesis management. This study shows that, when opting for revision arthroplasty, clinical peri-operative complications are similar with those associated with osteosynthesis treatment. Moreover, some authors propose that revision arthroplasty with diaphyseal support stems should be used in fixed-implant B1 fractures with non-favourable fracture characteristics for osteosynthesis (tip of stem fractures, transverse fractures, and cemented stems).[7,24,28,32] In the light of our findings, we suggest that, in cases of doubtful intra-operative stem fixation assessment, RA should be favoured, privileging early post-operative rehabilitation with similar rates of complications compared to OS.

This study was conducted not without some limitations. Firstly, the sample size was small, partly due to the relative scarcity of this type of fractures. The retrospective nature of this study implies some inherent design limitations such as the non-standardized clinical records and information loss. Even though the fixation assessment is systematized in our institution, it is an inherently operator-dependent evaluation, providing a degree of subjectivity to the intra-operative diagnosis of this fractures.

Radiological assessment was performed by a single hip pathology orthopaedic surgeon. This can present a risk for selection bias. However, when considering that overall B1 type fracture rate (4%) among all PHF was lower than what is described in most of the scientific literature,[7] it is unlikely that the number of B1 type fractures was overestimated. Finally, this was a unicentric study, which limited both the sample size and external validity of the results. These considerations underline the need for more multi-centric, prospective studies which can further the understanding of the management of this pathology.

CONCLUSION

In conclusion, we suggest that in the management of PHF without radiological signs of stem loosening, intra-operative stem-fixation assessment should be systematically preformed, and the surgical team should, accordingly, always be prepared for revision arthroplasty when addressing a PHF case.

Prémios e Apresentações Prévias
Presentations and Awards

Revision arthroplasty in Vancouver B1 peri-prosthetic hip fractures. Presented at Porto International Hip Meeting, Porto 1-2 July de 2022

Responsabilidades Éticas

Conflitos de Interesse: Os autores declaram a inexistência de conflitos de interesse na realização do presente trabalho.

Fontes de Financiamento: Não existiram fontes externas de financiamento para a realização deste artigo.

Confidencialidade dos Dados: Os autores declaram ter seguido os protocolos da sua instituição acerca da publicação dos dados de doentes.

Proteção de Pessoas e Animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pela Comissão de Ética responsável e de acordo com a Declaração de Helsínquia revista em 2013 e da Associação Médica Mundial.

Proveniência e Revisão por Pares: Não comissionado; revisão externa por pares.

Ethical Disclosures

Conflicts of Interest: The authors have no conflicts of interest to declare.

Financing Support: This work has not received any contribution, grant or scholarship

Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.

Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2013).

Provenance and Peer Review: Not commissioned; externally peer reviewed.

Declaração de Contribuição

JCP: Gestão do projeto, curadoria de dados, análise formal, investigação, metodologia, software, escrita da rascunho original, revisão e edição

AM: Curadoria de dados, investigação, escrita do rascunho original, revisão e edição

AC: Validação e edição

GC: Investigação, escrita do rascunho original, revisão e edição

JBT: Conceptualização, validação

EBR: Conceptualização, gestão do projeto e validação,

PV: Validação e supervisão

Todos autores aprovaram a versão final a ser publicada

Contributorship Statement

JCP: Project management, data curation, formal analysis, research, methodology, software, writing the original draft, review and editing

AM: Data curation, research, writing the original draft, review and editing

AC: Validation and editing

GC: Research, writing the original draft, revision and editing

JBT: Conceptualisation and validation

EBR: Conceptualisation, project management and validation,

PV: Validation and supervision

All authors approved the final version to be published

References

1. OECD. Health at a Glance 2019: OECD Indicators, Paris: OECD Publishing; 2019, doi: 10.1787/4dd50c09-en.
2. Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures classification and demographics of 1049 periprosthetic femoral fractures from the Swedish National Hip Arthroplasty Register. J Arthroplasty. 2005;20:857-65. doi:10.1016/j.arth.2005.02.001
3. Saskatchewan Health Authority. Annual report to the legislature 2018--2019: Healthy People, Healthy Saskatchewan. [accessed Jan 2023] Available at: https://www.saskhealthauthority.ca/sites/default/files/2023-07/Report-CEC-SHA-Annual-2018-19.pdf
4. Lindahl H. Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. Injury. 2007;38:651-4. doi:10.1016/j.injury.2007.02.048
5. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am.1999;30:183-90. doi:10.1016/s0030-5898(05)70073-0
6. Dehghan N, McKee MD, Nauth A, Ristevski B, Schemitsch EH. Surgical fixation of Vancouver type B1 periprosthetic femur fractures: a systematic review. J Orthop Trauma.2014;28:721-7. doi:10.1097/bot.0000000000000126
7. Patsiogiannis N, Kanakaris NK, Giannoudis PV. Periprosthetic hip fractures: an update into their management and clinical outcomes. EFORT Open Rev. 2021;6:75-92. doi:10.1302/2058-5241.6.200050
8. Moreta J, Aguirre U, de Ugarte OS, Jáuregui I, Mozos JL. Functional and radiological outcome of periprosthetic femoral fractures after hip arthroplasty. Injury. 2015;46:292-8. doi:10.1016/j.injury.2014.07.013
9. Moreta J, Uriarte I, Ormaza A, Mosquera J, Iza K, Aguirre U, et al. Outcomes of Vancouver B2 and B3 periprosthetic femoral fractures after total hip arthroplasty in elderly patients. Hip Int. 2019;29:184--90. doi:10.1177/1120700018772163
10. Boylan MR, Riesgo AM, Paulino CB, Slover JD, Zuckerman JD, Egol KA. Mortality following periprosthetic proximal femoral fractures versus native hip fractures. J Bone Joint Surg Am. 2018;100:578-85. doi: 10.2106/JBJS.17.00539.
11. Ciriello V, Chiarpenello R, Tomarchio A, Marra F, Egidio AC, Piovani L. The management of Vancouver B1 and C periprosthetic fractures: radiographic and clinic outcomes of a monocentric consecutive series. Hip Int. 2020;30:94-100. doi:10.1177/1120700020971727
12. Chakrabarti D, Thokur N, Ajnin S. Cable plate fixation for Vancouver type-B1 periprosthetic femoral fractures-Our experience and identification of a subset at risk of non-union. Injury. 2019;50:2301-5. doi:10.1016/j.injury.2019.10.012
13. Phillips JR, Boulton C, Morac CG, Manktelov AR. What is the financial cost of treating periprosthetic hip fractures? Injury. 2011;42:146-9. doi:10.1016/j.injury.2010.06.003
14. Jones AR, Williams T, Paringe V, White SP. The economic impact of surgically treated peri-prosthetic hip fractures on a university

teaching hospital in Wales 7.5-year study. Injury. 2016;47:428-31. doi:10.1016/j.injury.2015.11.012

15. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect. 1995;44:293-304.
16. Brady OH, Garbuz DS, Masri BA, Duncan CP. The reliability and validity of the Vancouver classification of femoral fractures after hip replacement. J Arthroplasty. 2000;15:59-62. doi:10.1016/s0883-5403(00)91181-1
17. Rayan F, Dodd M, Haddad FS. European validation of the Vancouver classification of periprosthetic proximal femoral fractures. J Bone Joint Surg Br. 2008;90:1576-9. doi:10.1302/0301-620x.90b12.20681
18. Masri BA, Meek RM, Duncan CP. Periprosthetic fractures evaluation and treatment. Clin Orthop Relat Res. 2004:80-95. doi:10.1097/00003086-200403000-00012
19. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties: a 40-year experience. Bone Joint J. 2016;98-b:468-74. doi:10.1302/0301-620x.98b4.37203
20. Lindahl H, Garellick G, Regnér H, Herberts P, Malchau H. Three hundred and twenty-one periprosthetic femoral fractures. J Bone Joint Surg Am. 2006;88:1215-22. doi:10.2106/jbjs.E.00457
21. Corten K, Vanrykel F, Bellemans J, Frederix PR, Simon JP, Broos PL. An algorithm for the surgical treatment of periprosthetic fractures of the femur around a well-fixed femoral component. J Bone Joint Surg Br. 2009;91:1424-30. doi:10.1302/0301-620x.91b11.22292
22. Berry DJ. Management of periprosthetic fractures: the hip. J Arthroplasty. 2002;17:11-3. doi:10.1054/arth.2002.32682
23. Lindahl H, Malchau H, Odén A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. J Bone Joint Surg Br. 2006;88:26-30. doi:10.1302/0301-620x.88b1.17029
24. Okudera Y, Kijima H, Yamada S, Konishi N, Kubota H, Tazawa H, et al. The location of the fracture determines the better solution, osteosynthesis or revision, in periprosthetic femoral fractures. J Orthop. 2020;22:220-4. doi:10.1016/j.jor.2020.05.007
25. Froberg L, Troelsen A, Brix M. Periprosthetic Vancouver type B1 and C fractures treated by locking-plate osteosynthesis: fracture union and reoperations in 60 consecutive fractures. Acta Orthop. 2012;83:648-52. doi:10.3109/17453674.2012.747925
26. Laurer HL, Wutzler S, Possner S, Geiger EV, El Saman A, Marzi I, et al. Outcome after operative treatment of Vancouver type B1 and C periprosthetic femoral fractures: open reduction and internal fixation versus revision arthroplasty. Arch Orthop Trauma Surg. 2011;131:983-9. doi:10.1007/s00402-011-1272-y
27. Buttaro MA, Farfalli G, Paredes Núñez M, Comba F, Piccaluga F. Locking compression plate fixation of Vancouver type-B1 periprosthetic femoral fractures. J Bone Joint Surg Am. 2007;89:1964-9. doi:10.2106/jbjs.F.01224
28. Yasen AT, Haddad FS. The management of type B1 periprosthetic femoral fractures: when to fix and when to revise. Int Orthop. 2015;39:1873-9. doi:10.1007/s00264-014-2617-2
29. Tower SS, Beals RK. Fractures of the femur after hip replacement: the Oregon experience. Orthop Clin North Am. 1999;30:235-47. doi:10.1016/s0030-5898(05)70078-x
30. Cassidy JT, Kenny P, Keogh P. Failed osteosynthesis of cemented B1 periprosthetic fractures. Injury. 2018;49:1927-30. doi:10.1016/j.injury.2018.07.030
31. Gutiérrez Del Alamo J, Garcia-Cimbrelo E, Castellanos V, Gil-Garay E. Radiographic bone regeneration and clinical outcome with the Wagner SL revision stem: a 5-year to 12-year follow-up study. J Arthroplasty. 2007;22:515-24. doi:10.1016/j.arth.2006.04.029
32. Tsiridis E, Pavlou G, Venkatesh R, Bobak P, Gie G. Periprosthetic femoral fractures around hip arthroplasty: current concepts in their management. Hip Int. 2009;19:75-86. doi:10.1177/112070000901900201